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A Global Analysis of Energy Prices and Agriculture

Bradley J. McDonald
Stephen W. Martinez
Miranda Otradovsky
James V. Stout

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Abstract

A multiregion computable general equilibrium (CGE) model was used to assess the longrun effects of higher energy prices on agricultural production, prices, and trade. An increase in the price of energy enters farmers' cost functions through direct energy use and through the indirect influence of energy prices on intermediate inputs, especially fertilizers. The multiregion feature of the model allows us to include the effects of energy price shocks on economies of other regions and to assess price changes in a global context. Because farming is highly energy-intensive, agricultural output falls more than output in the manufacturing and services sectors of each region of the model. Real returns to farmland, a good indicator of farm welfare, fall in each of the four regions.

Keywords: Trade, computable general equilibrium (CGE) model, energy prices.

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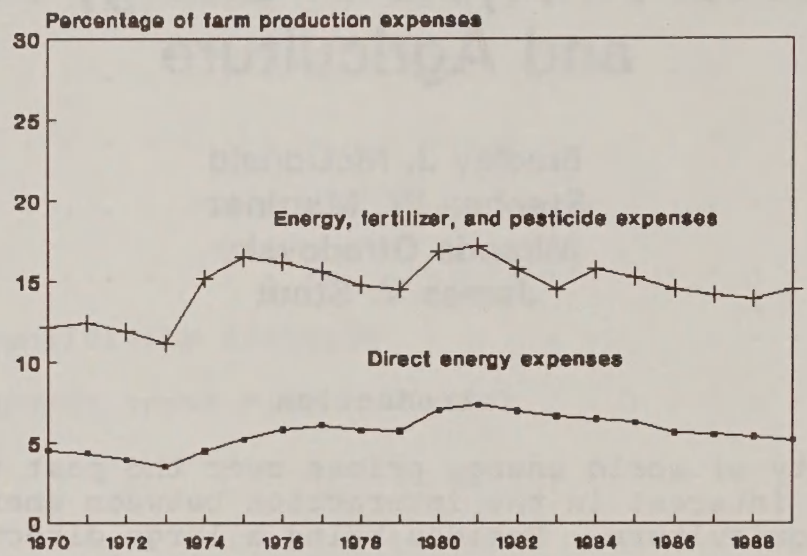
Introduction

The volatility of world energy prices over the past two decades has fostered interest in the interaction between energy price shocks and agriculture. Besides being a large direct consumer of energy, agriculture uses two energy-intensive inputs: pesticides and fertilizers. During the past 20 years, farm direct energy expenses for fuels, oils, and electricity have accounted for as little as 3.5 percent of total farm production expenses (1973) and as much as 7.4 percent (1981). These direct expenditures, together with expenditures for pesticides and fertilizers, have totaled from 11.2 percent (1973) to 17.2 percent (1981) of total farm production expenses (fig. 1). Energy cost shares for agriculture in other countries tend to be even greater than those for the United States, suggesting that variability in energy prices can be a greater problem for U.S. competitors (table 1).

Other studies analyzing the relationship between energy and agriculture have used either partial-equilibrium or single-country models. Christensen and Heady (1983) examined the effects of higher energy prices on the U.S. agricultural input sector by using an econometrically estimated simulation model. Penn and others (1976) developed a linear programming model to simulate the effects of various types of energy shortages on the U.S. economy. They found that, due to differences in direct energy use and the energy intensity of inputs, the effects of energy shortages vary among sectors of the U.S. economy. Their results suggested that output in the agriculture, forestry, and fisheries sector would decline by 6 percent if crude petroleum imports fell by 1.5 million barrels per day. Timmer (1975) used a simple macroeconomic model to distinguish longrun from shortrun relationships between energy and food prices. The longrun response of the supply of food grains to energy price increases was found to be less than half that of the shortrun response. This paper uses a multiregion computable general equilibrium (CGE) model to assess the longrun effects of higher energy prices on agricultural production, prices, and trade. The CGE methodology has been applied to several issues involving agriculture, including agricultural trade policy and tax reform.

The modeling of factor markets and nonagricultural sectors of the economy allows a more accurate portrayal of factor movements and

Figure 1--Energy use in U.S. agriculture



Source: Economic Indicators of the Farm Sector (1989).

the effects of energy price changes on nonagricultural prices. The energy intensity of these sectors, as well as that of agriculture, is included in the model.[1] It is the relative energy intensity of a sector that primarily determines its longrun performance in response to an energy price shock. Table 1 shows the initial cost shares of direct energy use for each sector of the four regions of the model. Indirect energy use is also substantial, with fertilizers and pesticides being important energy-intensive inputs into agricultural production.

The multiregion feature of the model allows us to include the effects of energy price shocks on other economies and to accurately assess world price changes. In a multiregion model, differences in energy intensity across regions can be considered, sometimes with implications different from single-country models. Suppose, for example, that agriculture is the most energy-intensive sector in the domestic economy. A single-country analysis would indicate that agricultural output would contract if energy prices rise. Now assume that in other regions agriculture is still more energy-intensive than it is domestically and that agricultural demand is highly price-inelastic. A multiregion analysis then indicates a smaller contraction or even an expansion in domestic agricultural output. The multiregion approach used here also offers the advantage of

---

[1]The model considers a wide range of economic factors: (1) initial energy cost shares in agriculture versus nonagriculture, (2) initial energy cost share in domestic versus foreign agriculture, (3) existing patterns of trade between the four regions of the world, using the Armington assumption of product differentiation by region of origin, (4) the effect of energy price changes on current account balances of the four regions, (5) the immobility of land out of or into agricultural uses, and (6) the influence of higher oil prices on the incomes of oil exporters.

Table 1--Cost shares of direct energy use, by sector

Region	Crops	Livestock	Fertilizer	Manufacturing	Services and other
			Percent		
United States	5.2	2.4	20.0	3.3	2.5
Other OECD[1]	7.0	3.0	20.0	4.2	3.1
Oil exporters	9.0	5.7	32.6	5.4	4.5
Rest of world	9.8	6.1	35.7	8.1	5.2

[1]Organization for Economic Cooperation and Development.
Sources: Survey of Current Business (1990) and Eurostat National Accounts ESA: Input-Output Tables 1980 (1986).

identifying changes in trade patterns resulting from an energy price shock.

The Model

The model begins with the specification of consumer utility functions and industry production functions. Consumers choose the combination of goods that maximizes utility subject to an income constraint and consumer prices; they receive income from an exogenous endowment of the production factors. Producers choose their inputs to minimize costs, given their production functions and input prices.

Several simplifying assumptions are made. Consumers are assumed to spend their entire income, so there is no saving or investment. Government policy is not examined, and no taxes, subsidies, or regulations are included in the model. The model is static, nonspatial, and deterministic.

We divide the world economy into four regions: the United States, other member countries of the Organization for Economic Cooperation and Development (OECD), a group of oil exporters,[2] and the rest of the world. Each region has a single "representative" consumer. The consumer utility functions are of the constant elasticity of substitution (CES) form:[3]

(1) $$U_r = \sum_{i=1}^{5} b_{ir} \; X_{ir}^{-\rho_r}$$

[2]The group consists of Algeria, Cameroon, Egypt, Indonesia, Mexico, Saudi Arabia, and Trinidad and Tobago. These countries were chosen because of data availability.

[3]Equation 1 is actually a monotonic transformation of the typical CES representation. Used on the demand side, this simply rescales the utility contours, with no effect on consumer behavior.

where U_r is the utility of region r, X_{ir} is the consumption of good i in region r, ρ is an elasticity parameter, and b_{ir} is a distribution parameter. The resulting demand functions are:

(2) $$X_{ir} = \frac{b_{ir}^{\sigma_r}}{P_{ir}^{\sigma_r} \sum_{j=1}^{5} b_{jr}^{\sigma_r} P_{jr}^{1-\sigma_r}} I_r$$

where I_r is the income of consumer (that is, region) r, P_{ir} is the price of good i in region r, and $\sigma_r = 1/(1-\rho_r)$ is the elasticity of substitution. A nested CES structure allows for more detailed specification of substitution relationships. Instead of the single-level function described in equation 1, this model in fact employs two demand-side nests consisting of food and nonfood (diagram 1). The food nest consists of crops and livestock, while the nonfood nest consists of manufacturing, energy, and services and other.

Each region has five industries: crops, livestock, fertilizers, manufacturing, and other goods and services. (Energy is treated as a factor, with a specified endowment level.) A single, perfectly competitive, representative producer is assumed in each of the model's 20 industries (that is, 5 industries in each of the 4 regions). Industry production functions are also CES:

(3) $$Y_{ir} = \gamma_{ir} \left[\sum_j \delta_{ijr} X_{ijr}^{-\rho_{ir}}\right]^{-\frac{1}{\rho_{ir}}}$$

where Y_{ir} is the output of industry i in region r, X_{ijr} is the input of good or factor j in the production of industry i in region r, δ_{ijr} is the distribution parameter for good j in the production of i in region r, and γ_{ir} is an efficiency parameter. The input demand functions that result from cost minimization are:

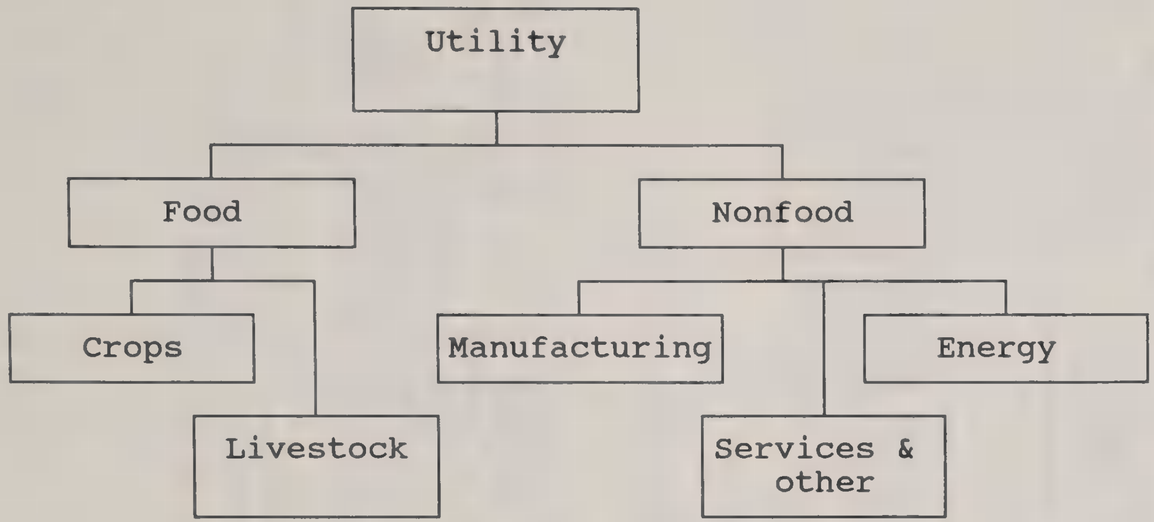
(4) $$X_{ijr} = \frac{\delta_{ijr}^{\sigma_{ir}}}{P_{ir}^{\sigma_{ir}} \left[\sum_j \delta_{ijr}^{\sigma_{ir}} P_{jr}^{1-\sigma_{ir}}\right]^{-\frac{1}{\rho_{ir}}}} Y_{ir}$$

where $\sigma_{ir} = 1/(1-\rho_{ir})$ is the elasticity of substitution between inputs in the production function. Like consumption, the production structure of this model uses a nested CES structure (diagram 1). The top-level nest consists of all intermediate inputs, energy, and the value-added nest. The value-added nest consists of labor, capital, and, in the agricultural industries, land. The elasticities used to represent the technology and preferences in the model are listed in table 2.

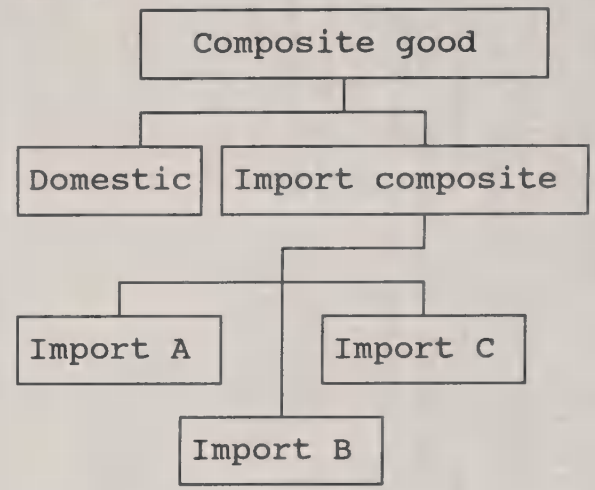
Goods are assumed to be differentiated based on the region of production. For example, crops produced in the United States are

Diagram 1

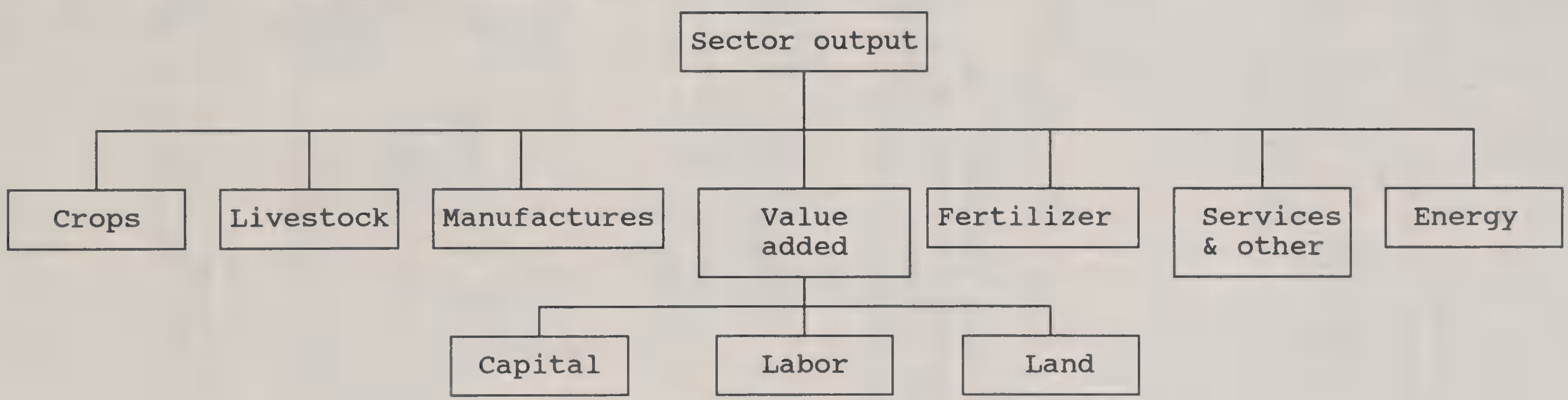
CES nesting of the utility functions



CES nesting of the border aggregation functions



CES nesting of the production functions



slightly different from crops produced in any other region. This "Armington" assumption is incorporated in the model through the use of border aggregation functions (BAF). These functions, 1 per region per industry (20 total), combine imports with the domestic good to form a "composite" good. For example, the BAF for U.S. livestock will combine livestock produced in the United States with livestock produced in other OECD countries, oil exporters, and the rest of the world according to a CES function (diagram 1). The elasticity of substitution in this function specifies the degree of heterogeneity assumed for that good: if the elasticity of substitution is very high, then goods from different regions are nearly perfect substitutes. A typical BAF is specified as follows:

(5) $$X_{ir}^{C} = \left[\sum_{s=1}^{4} m_{irs} X_{irs}^{-\rho_{ir}}\right]^{-\frac{1}{\rho_{ir}^{C}}}$$

where X_{ir}^{C} is the total amount of composite good i used (in consumption or as an intermediate input) in region r, X_{irs} is the amount of good i originating in region s used in region r, m_{irs} is a share parameter, and ρ_{ir}^{C} is an elasticity parameter. The Armington elasticities of substitution used in this model are listed in table 2. Sensitivity analysis performed on these key elasticities is described in Appendix A.

The model is closed by equating consumer income with spending. Factor income is determined by the price of each factor and the size of the region's (consumer's) endowment of each factor. Energy, land (agricultural industries), labor, and capital are the four factors of production; except for energy, these factors are perfectly immobile internationally. The income available to each consumer is:

(6) $$I_{r} = \sum_{f=1}^{4} w_{fr} E_{fr} - CA_{r}^{0}$$

where W_{fr} is the price of factor f in region r, E_{fr} is the endowment of factor f in region r, and CA_{r}^{0} is the benchmark equilibrium current account balance of region r. (Each region is assumed to maintain a constant current account balance; prices in each region adjust in order to maintain the current account balance.) The model is calibrated to 1987 data and is solved using the CGE software MPS/GE (Rutherford, 1989). Equilibrium is attained when supply equals demand in all markets, all factors of production are fully employed, all firms are making normal profits, and consumer income is exhausted. We include the complete MPS/GE input file for this model as Appendix B.

Table 2--Selected model parameters

Type of elasticity and sector	Elasticities		
Elasticities of substitution in production:	Between value added and intermediates		Among value added components
Crops	0.2		0.4
Livestock	.2		.4
Fertilizer	.2		.4
Manufacturing	.2		.4
Services and other	.2		.4
Armington elasticities of substitution:	Domestic versus imports		Among imports
Crops	3.0		4.0
Livestock	3.0		4.0
Fertilizer	6.0		7.0
Manufacturing	2.0		2.5
Services and other	2.0		2.5
Elasticities of substitution in consumer demand:	Between agricultural and nonagricultural goods	Between crops and livestock	Between energy, manufacturing and other
All regions	.15	0.5	.5

Source: Parameters were selected by the authors based on existing econometric estimates and parameters used in other CGE models.

Model Results

The results of a 25-percent increase in the price of energy are summarized in table 3.[4] This price increase was brought about by a reduction in the (exogenous) supply of energy. Several important points must be considered when interpreting the results. First, the inflationary effect of an oil price shock is omitted from a CGE analysis in which only real quantities and prices are included: a numeraire price is chosen and fixed throughout the analysis (here we chose the rest of the world consumer price index as numeraire). Second, the model abstracts from any adjustment costs that are incurred when energy prices

[4]A 25-percent increase in the energy price would result from approximately a 60-percent increase in the crude oil price. Here, the energy price increase was brought about by a reduction in the energy endowment of the oil exporters and rest of world regions. As a share of GNP, the oil exporters' energy endowment was reduced more than that of the rest of the world, and the oil exporters' energy export revenues fall. The rest of the world can be interpreted as representing those countries that reap a windfall from higher energy prices. When energy supply in these two regions is reduced proportionately, the qualitative results for the United States and other OECD countries are unchanged.

Table 3--Results of a 25-percent energy price increase

Type of change and sector	Change in-- United States	Other OECD	Oil exporters	Rest of the world
	Percent			
Production volume:				
Crops	-1.2	-2.2	-1.2	-1.5
Livestock	-.6	-.4	-2.6	-.7
Manufacturing	-.5	-.4	-.2	-1.5
Services and other	-.1	-.3	-.6	0
Export volume:				
Crops	-1.5	-2.6	10.2	-2.6
Livestock	-3.6	.6	9.1	-3.4
Manufacturing	-1.4	.2	6.2	-2.5
Services and other	-2.5	.2	8.1	-.3
Import volume:				
Crops	-.6	-2.3	-6.9	-.4
Livestock	2.3	-3.2	-8.8	1.7
Manufacturing	.2	-1.8	-6.2	.5
Services and other	1.7	-.9	-7.8	0
Real prices:				
Crops	.5	1.6	0	.5
Livestock	-.4	-.5	-.9	-.7
Manufacturing	-.2	.2	-.8	0
Services and other	-.8	-.8	-2.4	-1.9
Land rental rate	-3.5	-2.6	-6.0	-4.9
Real exchange rate (trade-weighted)	+.4	-.9	-1.8	+.9

Source: Model results.

change and input use in production must be restructured; all the results of this model are comparative static results that would be attained only after an oil price change had become "permanent."

The fertilizer sector, not shown in table 3 because it is such a small part of the economy, is hardest hit by the energy price increase because of its greater than 20-percent direct energy cost share (see table 1). Among the other sectors, crops output falls the most, crops being the sector that employs the most energy, both directly and indirectly (through fertilizer and pesticide use). The reduction in crops production is greatest in the other OECD region, where output falls 2.2 percent.

Higher energy prices affect the livestock sector indirectly by causing an increase in feed prices. Production levels of the

livestock sectors in the United States and other OECD regions decline only slightly (0.6 percent and 0.4 percent); however, since real livestock prices fall, there is a moderate decline in the value of livestock production in each region.

Initial cost shares of energy in the nonagricultural sectors are smaller than energy cost shares in agriculture, and the model confirms that output in the nonagricultural sectors is less sensitive to energy price changes. For example, other OECD industrial output falls by 0.4 percent and the services and other sector contracts by 0.3 percent. Model results also seem to reflect the energy intensity of agriculture in other regions relative to the United States, as the magnitude of the decline in crops output in the United States is smaller than it is in two of the other three regions.

Because land is a fixed factor in agriculture, the real price of farmland is a good indicator of what happens to farm operators in the long run following an energy price shock. Real returns to farmland fall in each region. The drop in the U.S. land price of 3.5 percent is similar to that resulting from a 20-percent multilateral agricultural policy liberalization by industrialized market economies in a similar model (McDonald, 1990).

Relative price levels[5] (across regions) adjust in the model to maintain the current account balance. In this experiment, the trade-weighted value of the United States and the rest of the world currencies increase in value (by 0.4 percent and 0.9 percent, respectively) while currencies of the other OECD and oil exporter regions fall in value (0.9 percent and 1.8 percent, respectively).[6] This exchange rate realignment plays an important role in determining changes in trade patterns (summarized in table 3). For the United States, changes in the exchange rate cause reductions in the export volume of each sector and increases in import volume of livestock, manufacturing, and services and other. The opposite pattern is evident for other OECD: all imports fall, while exports of livestock, manufacturing, and services and other increase. Overall, a slight antitrade bias is evident in the experiment: the volume of total world trade falls by 0.6 percent.[7]

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[5]All prices in this model are denominated in a common currency, hence there are no nominal exchange rates. Changes in relative price levels across regions can be thought of as representing real exchange rate changes.

[6]Recall that the energy price increase in the model was brought about by a reduction in the endowment of energy in the rest of the world (ROW) and oil exporters regions. The energy price increase is substantially greater than the percentage reduction in the ROW supply of energy; to head off an incipient surplus in the ROW current account, the value of the ROW currency increases. The situation for oil exporters is quite different; they face a relatively large reduction in their energy endowment, and their currency must drop in value in order to avoid a current account deficit. The U.S. currency increases in value primarily because most of its trade is with the other OECD nations, which are more energy-dependent than the United States.

[7]When measured as a share of world GNP, world trade is virtually unchanged.

Sensitivity analysis was performed on some of the model's key elasticity parameters. Results were obtained under different assumptions regarding agricultural trade elasticities and nonagricultural trade elasticities. The model was only mildly sensitive to these changes. For example, despite large changes in the elasticities, the energy price experiment always generated a 3.3- to 3.9-percent decrease in the real price of U.S. farmland. Results of the sensitivity analysis are given in Appendix A.

Conclusions

This paper analyzed the effects of large energy price changes on the agricultural sectors of different regions. To accurately gauge the longrun effects of such a shock, one must consider not only the energy intensity of agriculture but also the energy intensity of other sectors of the economy. Because energy shocks are typically global, it is also important to use a multiregion global model to capture the influence of possible changes in comparative advantage.

Our model results indicate that, in the long run, each sector of the economy would contract in each of the four regions, due to the assumed reduction in supply of an important input, energy. The contraction tends to be greatest in the agricultural sectors, especially the highly energy-intensive crops sector. Sectors with low energy intensity tend to contract the least. However, even a very large and sustained increase in the price of energy leads to only a small decline in agricultural output and agricultural land prices.

Several extensions to this research could prove beneficial. The energy input could be modeled in more detail by including various types of energy (petroleum, electricity, and others) along with the extent to which particular industries rely on each type of energy. While the substitutability between energy sources can be considerable, it is never complete. In fact, industries and regions that rely more heavily on petroleum than on other types of energy will be hit hardest by an oil shock. Altering the regional aggregation of the model--perhaps to break out centrally planned or developing economies--would permit more detailed exploration of the regional effects associated with an energy price shock. In the United States, higher grain prices would reduce budget outlays for deficiency payments (assuming fixed target prices); this could also be assessed. Finally, alternative policy responses to an energy price shock could be explored and analyzed.

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Appendix A: Sensitivity Analysis

Parameter values for the elasticities of substitution in the model were given in table 2 of the text. It is a good and common practice in CGE modeling to analyze the "sensitivity" of model results to changes in these parameters. This typically means that all substitution elasticities in the model are increased (decreased) by the same percentage; the possibility that some elasticities are too high while others are too low is usually not addressed.

Here we report model results under alternative assumptions about the Armington elasticities of substitution, the elasticity parameters we felt were most likely to substantially affect the results. (Recall that these elasticities determine the degree of substitutability between imports and domestic goods.) First, the Armington elasticities for agricultural goods were decreased (increased) by 50 percent; then the Armington elasticites for nonagricultural goods were decreased (increased) by 50 percent. The oil price experiment, described in the main text of this paper, was conducted under these alternative assumptions. Appendix table 1 lists the results for selected U.S. variables. It suggests that our results are robust with regard to alternative Armington elasticities for both agriculture and nonagriculture.

Appendix table 1--Results of sensitivity analysis on Armington elasticities for selected variables in the United States

Type of elasticity and sector	Elasticities for--				
	Base	Ag-lo	Ag-hi	Nonag-lo	Nonag-hi
	Percent change				
U.S. output of:					
Crops	-1.2	-1.3	-1.0	-1.4	-1.1
Livestock	-.6	-.4	-.9	-.6	-.5
Manufactures	-.5	-.5	-.5	-.5	-.4
Other	-.1	-.1	-.1	-.1	-.2
U.S. real price of:					
Farmland	-3.5	-3.4	-3.5	-3.9	-3.3
Crops	.5	.6	.5	.4	.6
Livestock	-.4	-.4	-.4	-.4	-.3

Ag-lo: Elasticities reduced for crops and livestock by 50 percent.
Ag-hi: elasticities increased for crops and livestock by 50 percent.
Nonag-lo: elasticities reduced for manufacturing and other by 50 percent.
Nonag-hi: elasticities increased for manufacturing and other by 50 percent.

Appendix B: MPS/GE Input File

For details of the MPS/GE modeling system, see Rutherford (1989).

```
*  OIL MODEL
* Regions: U.S., other OECD, oil
exporters, ROW
* Goods: crops, livestock, chem. &
fertilizer, other mfrs., services &
others
*
*MODEL: oil
$ITLIMT:10
$CONTOL:0.00005
$SECTORS:
*               Activity
*Prod'n      Export       Import
 U_CROPS     U_CROPSX     U_CROPSD
 U_LVSTK     U_LVSTKX     U_LVSTKD
 U_CHFER     U_CHFERX     U_CHFERD
 U_MFRS      U_MFRSX      U_MFRSD
 U_OTHER     U_OTHERX     U_OTHERD
*
 E_CROPS     E_CROPSX     E_CROPSD
 E_LVSTK     E_LVSTKX     E_LVSTKD
 E_CHFER     E_CHFERX     E_CHFERD
 E_MFRS      E_MFRSX      E_MFRSD
 E_OTHER     E_OTHERX     E_OTHERD
*
 O_CROPS     O_CROPSX     O_CROPSD
 O_LVSTK     O_LVSTKX     O_LVSTKD
 O_CHFER     O_CHFERX     O_CHFERD
 O_MFRS      O_MFRSX      O_MFRSD
 O_OTHER     O_OTHERX     O_OTHERD
*
 R_CROPS     R_CROPSX     R_CROPSD
 R_LVSTK     R_LVSTKX     R_LVSTKD
 R_CHFER     R_CHFERX     R_CHFERD
 R_MFRS      R_MFRSX      R_MFRSD
 R_OTHER     R_OTHERX     R_OTHERD
*
*          Utility functions
 U_U  E_U   O_U   R_U
*
$COMMODITIES:
 RU UU EU OU
 UCROPS ULVSTK UCHFER UMFRS UOTHER
 UCROPSX ULVSTKX UCHFERX UMFRSX
UOTHERX
 UCROPSM ULVSTKM UCHFERM UMFRSM
UOTHERM
*
 ECROPS  ELVSTK  ECHFER  EMFRS  EOTHER
 ECROPSX ELVSTKX ECHFERX EMFRSX
EOTHERX
 ECROPSM ELVSTKM ECHFERM EMFRSM
EOTHERM
*
 OCROPS  OLVSTK  OCHFER  OMFRS  OOTHER
 OCROPSX OLVSTKX OCHFERX OMFRSX
OOTHERX
 OCROPSM OLVSTKM OCHFERM OMFRSM
OOTHERM
*
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 RCROPSX RLVSTKX RCHFERX RMFRSX
ROTHERX
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 RCROPSM RLVSTKM RCHFERM RMFRSM
ROTHERM

*
* Factors:
 ENERGY
 ULAND ULABOR UCAP
 ELAND ELABOR ECAP
 OLAND OLABOR OCAP
 RLAND RLABOR RCAP
*
$CONSUMERS:
 UC  EC  OC  RC
*
$PROD:U_CROPS      s:0.2 a:0.4
 O:UCROPS          X:45.695
 I:ULAND           X:10.237     a:
 I:ULABOR          X:3.519      a:
 I:UCAP            X:13.344     a:
 I:UCROPSM         X:3.153
 I:UOTHERM         X:2.774
 I:UCHFERM         X:7.792
 I:UMFRSM          X:2.500
 I:ENERGY          X:2.376
*
$PROD:U_LVSTK     s:0.2  a:0.4
 O:ULVSTK          X:73.344
 I:ULAND           X:4.911   a:
 I:ULABOR          X:11.772  a:
 I:UCAP            X:18.398  a:
 I:UCROPSM         X:21.741
 I:UOTHERM         X:7.763
 I:UMFRSM          X:7.0
 I:ENERGY          X:1.759
*
$PROD:U_CHFER      s:0.2 a:0.4
 O:UCHFER          X:8.500
 I:UCAP            X:0.765        a:
 I:ULABOR          X:1.445        a:
 I:ENERGY          X:1.700
 I:UMFRSM          X:3.57
 I:UOTHERM         X:1.02
*
$PROD:U_MFRS       s:0.2 a:0.4
 O:UMFRS           X:1600
 I:ULABOR          X:405 a:
 I:UCAP            X:270 a:
 I:ENERGY          X:53
 I:UMFRSM          X:586
 I:UOTHERM         X:286

$PROD:U_OTHER      s:0.2 a:0.4
 O:UOTHER          X:2900
 I:ULABOR          X:1188       a:
 I:UCAP            X:771        a:
 I:ENERGY          X:72
 I:UMFRSM          X:165
 I:UOTHERM         X:704


$PROD:E_CROPS      s:0.2 a:0.4
 O:ECROPS          X:45.9 A:EC  S:0.80
 I:ELAND           X:9.912      a:
```

```
 I:ELABOR           X:9.912      a:
 I:ECAP             X:20.413     a:
 I:ECROPSM          X:5.782
 I:EOTHERM          X:8.26
 I:ENERGY           X:5.782
 I:EMFRSM           X:8.26
 I:ECHFERM          X:14.279
*
$PROD:E_LVSTK       s:0.2 a:0.4 a:0.6
 O:ELVSTK           X:163.5  S:1.00612
 I:ELAND            X:30.96      a:
 I:ELABOR           X:68.7856    a:
 I:ECAP             X:108.72     a:
 I:ECROPSM          X:37.535
 I:EOTHERM          X:39.36      a:
 I:ENERGY           X:9.84
 I:EMFRSM           X:32.8       a:
*
$PROD:E_CHFER       s:0.2 a:0.4
 O:ECHFER           X:14.50
 I:ECAP             X:1.305      a:
 I:ELABOR           X:2.465      a:
 I:ENERGY           X:2.90
 I:EMFRSM           X:6.09
 I:EOTHERM          X:1.74

$PROD:E_MFRS        s:0.2 a:0.4
 O:EMFRS            X:1985
 I:ELABOR           X:502        a:
 I:ECAP             X:325        a:
 I:ENERGY           X:84
 I:EMFRSM           X:719
 I:EOTHERM          X:355

$PROD:E_OTHER       s:0.2 a:0.4
 O:EOTHER           X:3405
 I:ELABOR           X:1394       a:
 I:ECAP             X:901        a:
 I:ENERGY           X:107
 I:EMFRSM           X:187
 I:EOTHERM          X:816

$PROD:O_CROPS       s:0.2 a:0.4
 O:OCROPS           X:39.393
 I:OLAND            X:8.51       a:
 I:OLABOR           X:5.994      a:
 I:OCAP             X:9.25       a:
 I:OCROPSM          X:2.59
 I:OOTHERM          X:2.22
 I:ENERGY           X:3.586
 I:OMFRSM           X:2.96
 I:OCHFERM          X:4.283
*
$PROD:O_LVSTK       s:0.2 a:0.4
 O:OLVSTK           X:15.422
 I:OLAND            X:1.5        a:
 I:OLABOR           X:3.0        a:
 I:OCAP             X:3.0        a:
 I:OCROPSM          X:4.5
 I:OOTHERM          X:1.35
 I:ENERGY           X:0.872
 I:OMFRSM           X:1.20

$PROD:O_CHFER       s:0.2 a:0.4
 O:OCHFER           X:4.157
 I:OCAP             X:0.315      a:
 I:OLABOR           X:0.595      a:
```

```
 I:ENERGY           X:1.357
 I:OMFRSM           X:1.47
 I:OOTHERM          X:0.42

$PROD:O_MFRS        s:0.2 a:0.4
 O:OMFRS            X:143.754
 I:OLABOR           X:42         a:
 I:OCAP             X:17         a:
 I:ENERGY           X:7.754
 I:OMFRSM           X:56
 I:OOTHERM          X:21

$PROD:O_OTHER       s:0.2 a:0.4
 O:OOTHER           X:214.692
 I:OLABOR           X:95         a:
 I:OCAP             X:52         a:
 I:ENERGY           X:9.692
 I:OMFRSM           X:12
 I:OOTHERM          X:46

$PROD:R_CROPS       s:0.2 a:0.4
 O:RCROPS           X:243.133
 I:RLAND            X:49.6       a:
 I:RLABOR           X:45.363     a:
 I:RCAP             X:51.9       a:
 I:RCROPSM          X:15.8
 I:ROTHERM          X:13.5
 I:ENERGY           X:23.752
 I:RMFRSM           X:15.8
 I:RCHFERM          X:27.418
*
$PROD:R_LVSTK       s:0.2 a:0.4
 O:RLVSTK           X:312.528
 I:RLAND            X:45.4       a:
 I:RLABOR           X:75.6       a:
 I:RCAP             X:45.4       a:
 I:RCROPSM          X:90.8
 I:ROTHERM          X:15.2
 I:ENERGY           X:19.128
 I:RMFRSM           X:21.0

$PROD:R_CHFER       s:0.2 a:0.4
 O:RCHFER           X:26.615
 I:RLABOR           X:3.842      a:
 I:RCAP             X:2.034      a:
 I:ROTHERM          X:2.712
 I:ENERGY           X:9.501
 I:RMFRSM           X:8.526

$PROD:R_MFRS        s:0.2 a:0.4
 O:RMFRS            X:1608.322
 I:RLABOR           X:493        a:
 I:RCAP             X:185        a:
 I:ENERGY           X:130.322
 I:RMFRSM           X:600
 I:ROTHERM          X:200

$PROD:R_OTHER       s:0.2 a:0.4
 O:ROTHER           X:2015.1
 I:RLABOR           X:882        a:
 I:RCAP             X:490        a:
 I:ENERGY           X:105.1
 I:RMFRSM           X:108
 I:ROTHERM          X:430

$PROD:U_CROPSX
 O:UCROPSX          X:26.618
```

```
 I:UCROPS            X:26.618
*
$PROD:U_LVSTKX
 O:ULVSTKX           X:6.055
 I:ULVSTK            X:6.055
*
$PROD:U_CHFERX
 O:UCHFERX           X:1.575
 I:UCHFER            X:1.575
*
$PROD:U_MFRSX
 O:UMFRSX            X:195.027
 I:UMFRS             X:195.027
*
$PROD:U_OTHERX
 O:UOTHERX           X:184.7
 I:UOTHER            X:184.7
*
$PROD:E_CROPSX
 O:ECROPSX           X:24.445
 I:ECROPS            X:24.445
*
$PROD:E_LVSTKX
 O:ELVSTKX           X:13.156
 I:ELVSTK            X:13.156
*
$PROD:E_CHFERX
 O:ECHFERX           X:2.077
 I:ECHFER            X:2.077
*
$PROD:E_MFRSX
 O:EMFRSX            X:478.47
 I:EMFRS             X:478.47
*
$PROD:E_OTHERX
 O:EOTHERX           X:229.6
 I:EOTHER            X:229.6
*
$PROD:O_CROPSX
 O:OCROPSX           X:4.99
 I:OCROPS            X:4.99
*
$PROD:O_LVSTKX
 O:OLVSTKX           X:0.704
 I:OLVSTK            X:0.704
*
$PROD:O_CHFERX
 O:OCHFERX           X:0.16
 I:OCHFER            X:0.16
*
$PROD:O_MFRSX
 O:OMFRSX            X:24.026
 I:OMFRS             X:24.026
*
$PROD:O_OTHERX
 O:OOTHERX           X:21.50
 I:OOTHER            X:21.50
*
$PROD:R_CROPSX
 O:RCROPSX           X:40.624
 I:RCROPS            X:40.624
*

$PROD:R_LVSTKX
 O:RLVSTKX           X:8.483
 I:RLVSTK            X:8.483
*
```

```
$PROD:R_CHFERX
 O:RCHFERX           X:1.281
 I:RCHFER            X:1.281
*
$PROD:R_MFRSX
 O:RMFRSX            X:223.597
 I:RMFRS             X:223.597
*
$PROD:R_OTHERX
 O:ROTHERX           X:177.5
 I:ROTHER            X:177.5
*
$PROD:U_CROPSD       s:3.0 a:4.0
 O:UCROPSM           X:36.482
 I:UCROPS            X:19.077
 I:ECROPSX           X:6.856      a:
 I:OCROPSX           X:1.98       a:
 I:RCROPSX           X:8.569      a:
*
$PROD:U_LVSTKD       s:3.0 a:4.0
 O:ULVSTKM           X:72.885
 I:ULVSTK            X:67.289
 I:ELVSTKX           X:3.973      a:
 I:OLVSTKX           X:0.305      a:
 I:RLVSTKX           X:1.318      a:
*
$PROD:U_CHFERD       s:6.0 a:7.0
 O:UCHFERM           X:7.792
 I:UCHFER            X:6.925
 I:ECHFERX           X:0.729      a:
 I:OCHFERX           X:0.028      a:
 I:RCHFERX           X:0.11       a:
*
$PROD:U_MFRSD        s:2.0 a:2.5
 O:UMFRSM            X:1732.133
 I:UMFRS             X:1404.973
 I:EMFRSX            X:220.856    a:
 I:OMFRSX            X:14.427     a:
 I:RMFRSX            X:91.877     a:
*
$PROD:U_OTHERD       s:2.0 a:2.5
 O:UOTHERM           X:2878.8
 I:UOTHER            X:2715.3
 I:EOTHERX           X:104 a:
 I:OOTHERX           X:5.5        a:
 I:ROTHERX           X:54         a:
*
$PROD:E_CROPSD       s:3.0 a:4.0
 O:ECROPSM           X:68.317
 I:ECROPS            X:21.455
 I:UCROPSX           X:14.935     a:
 I:OCROPSX           X:2.205      a:
 I:RCROPSX           X:29.722     a:
*
$PROD:E_LVSTKD       s:3.0 a:4.0
 O:ELVSTKM           X:160.767
 I:ELVSTK            X:150.344
 I:ULVSTKX           X:3.522      a:
 I:OLVSTKX           X:0.206      a:
 I:RLVSTKX           X:6.695      a:
*
$PROD:E_CHFERD       s:6.0 a:7.0
 O:ECHFERM           X:14.279
 I:ECHFER            X:12.423
 I:UCHFERX           X:0.724      a:
 I:OCHFERX           X:0.034      a:
 I:RCHFERX           X:1.098      a:
```

```
*
$PROD:E_MFRSD        s:2.0 a:2.5
 O:EMFRSM            X:1771.143
 I:EMFRS             X:1506.53
 I:UMFRSX            X:135.678    a:
 I:OMFRSX            X:5.92       a:
 I:RMFRSX            X:123.015    a:
*
$PROD:E_OTHERD       s:2.0 a:2.5
 O:EOTHERM           X:3403.7
 I:EOTHER            X:3175.4
 I:UOTHERX           X:108        a:
 I:OOTHERX           X:7.3        a:
 I:ROTHERX           X:113        a:
*
$PROD:O_CROPSD       s:3.0 a:4.0
 O:OCROPSM           X:42.834
 I:OCROPS            X:34.403
 I:UCROPSX           X:2.907      a:
 I:ECROPSX           X:3.191      a:
 I:RCROPSX           X:2.333      a:
*
$PROD:O_LVSTKD       s:3.0 a:4.0
 O:OLVSTKM           X:18.258
 I:OLVSTK            X:14.718
 I:ULVSTKX           X:0.591      a:
 I:ELVSTKX           X:2.479      a:
 I:RLVSTKX           X:0.47       a:
*
$PROD:O_CHFERD       s:6.0 a:7.0
 O:OCHFERM           X:4.283
 I:OCHFER            X:3.997
 I:UCHFERX           X:0.048      a:
 I:ECHFERX           X:0.165      a:
 I:RCHFERX           X:0.073      a:
*
$PROD:O_MFRSD        s:2.0 a:2.5
 O:OMFRSM            X:168.051
 I:OMFRS             X:119.728
 I:UMFRSX            X:9.016      a:
 I:EMFRSX            X:30.602     a:
 I:RMFRSX            X:8.705      a:
*
$PROD:O_OTHERD       s:2.0 a:2.5
 O:OOTHERM           X:237.692
 I:OOTHER            X:193.192
 I:UOTHERX           X:16         a:
 I:EOTHERX           X:18         a:
 I:ROTHERX           X:10.5       a:
*
$PROD:R_CROPSD       s:3.0 a:4.0
 O:RCROPSM           X:226.488
 I:RCROPS            X:202.509
 I:UCROPSX           X:8.776      a:
 I:ECROPSX           X:14.398     a:
 I:OCROPSX           X:0.805      a:
*
$PROD:R_LVSTKD       s:3.0 a:4.0
 O:RLVSTKM           X:312.884
 I:RLVSTK            X:304.045
 I:ULVSTKX           X:1.942      a:
 I:ELVSTKX           X:6.704      a:
 I:OLVSTKX           X:0.193      a:
*
$PROD:R_CHFERD       s:6.0 a:7.0
 O:RCHFERM           X:27.418
 I:RCHFER            X:25.334
 I:UCHFERX           X:0.803      a:
 I:ECHFERX           X:1.183      a:
 I:OCHFERX           X:0.098      a:
*
$PROD:R_MFRSD        s:2.0 a:2.5
 O:RMFRSM            X:1665.749
 I:RMFRS             X:1384.725
 I:UMFRSX            X:50.333     a:
 I:EMFRSX            X:227.012    a:
 I:OMFRSX            X:3.679      a:
*
$PROD:R_OTHERD       s:2.0 a:2.5
 O:ROTHERM           X:2014.6
 I:ROTHER            X:1837.6
 I:UOTHERX           X:60.7       a:
 I:EOTHERX           X:107.6      a:
 I:OOTHERX           X:8.7        a:
*
$PROD:U_U    s:0.15        a:0.5 b:0.5
 O:UU                X:3010.342
 I:UCROPSM           X:11.588     a:
 I:ULVSTKM           X:72.885     a:
 I:UMFRSM            X:968.063    b:
 I:UOTHERM           X:1877.243   b:
 I:ENERGY            X:80.563     b:
*
$PROD:E_U    s:0.15        a:0.5 b:0.5
 O:EU                X:3248.652
 I:ECROPSM           X:25.0       a:
 I:ELVSTKM           X:160.767    a:
 I:EMFRSM            X:817.993    b:
 I:EOTHERM           X:2183.34    b:
 I:ENERGY            X:61.552     b:
*
$PROD:O_U    s:0.15        a:0.5 b:0.5
 O:OU                X:326.626
 I:OCROPSM           X:35.744     a:
 I:OLVSTKM           X:18.258     a:
 I:OMFRSM            X:94.421     b:
 I:OOTHERM           X:166.702    b:
 I:ENERGY            X:11.501     b:
*
$PROD:R_U    s:0.15        a:0.5 b:0.5
 O:RU                X:2819.67
 I:RCROPSM           X:119.888    a:
 I:RLVSTKM           X:312.884    a:
 I:RMFRSM            X:912.423    b:
 I:ROTHERM           X:1353.188   b:
 I:ENERGY            X:121.287    b:
*
$DEMAND:UC
 D:UU                X:3010.342
 E:ULAND             X:15.148
 E:ULABOR            X:1609.736
 E:UCAP              X:1073.507
 E:ENERGY            X:173.1
 E:UU                X:44.293
 E:EU                X:47.487
 E:OU                X:4.86
 E:RU                X:42.211
*
$DEMAND:EC
 D:EU                X:3250.0532
 E:ELAND             X:40.872
 E:ELABOR            X:1977.1626
 E:ECAP              X:1356.438
 E:ENERGY            X:162
```

```
 E:UU            X:-27.632
 E:EU            X:-29.624
 E:OU            X:-3.032
 E:RU            X:-26.332
*
$DEMAND:OC
 D:OU            X:326.626
 E:OLAND         X:10.01
 E:OLABOR        X:146.589
 E:OCAP          X:81.565
 E:ENERGY        X:86.29
 E:UU            X:0.693
 E:EU            X:0.743
 E:OU            X:0.076
 E:RU            X:0.660
*
$DEMAND:RC
 D:RU            X:2874.073
 E:RLAND         X:95
 E:RLABOR        X:1499.805
 E:RCAP          X:774.334
 E:ENERGY        X:504.934
 E:UU            X:-17.354
 E:EU            X:-18.606
 E:OU            X:-1.904
 E:RU            X:-16.540
$SOLVE:
$MODEL:OILSHOCK
$DEMAND:OC
 D:OU            X:326.626
 E:OLAND         X:10.01
 E:OLABOR        X:146.589
 E:OCAP          X:81.565
*E:ENERGY        X:86.29
 E:ENERGY        X:64.456
 E:UU            X:0.693
 E:EU            X:0.743
 E:OU            X:0.076
 E:RU            X:0.660
$DEMAND:RC
 D:RU            X:2874.073
 E:RLAND         X:95
 E:RLABOR        X:1499.805
 E:RCAP          X:774.334
*E:ENERGY        X:504.934
 E:ENERGY        X:461.266
 E:UU            X:-17.354
 E:EU            X:-18.606
 E:OU            X:-1.904
 E:RU            X:-16.540
$SOLVE:
$STOP:
```

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